U.S. DEPARTMENT OF COMMERCE PATENT & TRADEMARK OFFICE

B/O Form PTO-1390 **Transmittal Letter to the United States Designated/Elected Office (DO/EO/US) Concerning a Filing Under *35 USC 371***		*Attorney's Docket Number* JEK/Hornung *U.S. Application Number (if known)* 09/786195
International Application Number PCT/EP99/06027	*International Filing Date* 17 August 1999	*Priority Date Claimed* 04 September 1998
Title of Invention METHOD AND DEVICE FOR CONTROLLING PAPER DOCUMENTS OF VALUE		
Applicant(s) for DO/EO/US Heinz HORNUNG et al.		

Applicant herewith submits to the United States Designated/Elected Office (DO/EO/US) the following items under *35 USC 371*:

1. ☒ This is a **FIRST** submission of items concerning a filing under *35 USC 371*.
2. ☐ This is a **SECOND** or **SUBSEQUENT** submission of items concerning a filing under *35 USC 371*.
3. ☒ This express request to begin national examination procedures *(35 USC 371(f))* at any time rather than delay examination until the expiration of the applicable time limit set in *35 USC 371(b)* and PCT Articles 22 and 39(1).
4. ☒ A proper Demand for International Preliminary Examination was made by the 19th month from the earliest claimed priority date.
5. ☒ A copy of the International Application as filed *35 USC 371(c)(2)*.
   a. ☐ is transmitted herewith (required only if not transmitted by the International Bureau).
   b. ☒ has been transmitted by the International Bureau.
   c. ☐ is not required, as the application was filed in the United States Receiving Office (RO/US).
6. ☒ A translation of the International Application into English *(35 USC 371(c)(2))*.
7. ☒ Amendments to the claims of the International Application under PCT Article 19 *(35 USC 371(c)(3))*
   a. ☐ are transmitted herewith (required only if not transmitted by the International Bureau).
   b. ☐ have been transmitted by the International Bureau.
   c. ☐ have not been made; however, the time limit for making such amendments has NOT expired.
   d. ☒ have not been made and will not be made.
8. ☐ A translation of the amendments to the claims under PCT Article 19 *(35 USC 371(c)(3))*.
9. ☒ An oath or declaration of the inventor(s) *(35 USC 371(c)(4))*. (☐ Executed ☒ Unexecuted)
10. ☒ A translation of the annexes to the International Preliminary Examination Report under PCT Article 36 *(35 USC 371(c)(5))*.

Items 11 to 16 below concern other document(s) or information included:

11. ☐ An Information Disclosure Statement under *37 CFR 1.97* and *1.98*.
12. ☐ An assignment document for recording. A separate cover sheet in compliance with *37 CFR 3.28* and *3.31* is included.
13. ☒ A **FIRST** preliminary amendment.
    ☐ A **SECOND** or **SUBSEQUENT** preliminary amendment.
14. ☐ A substitute specification.
15. ☐ A change of power of attorney and/or address letter.
16. ☒ Other items or information: 3 sheets formal drawings

Application Number (if Known) 09/786195	*International Application Number* PCT/EP99/06027	*Attorney's Docket Number* JEK/Hornung	
		Calculations	**PTO USE ONLY**
17. The following fees are submitted: **Basic National Fee *(37 CFR 1.492(a)(1)-(5))*:** ☒ Search report has been prepared by the EPO or JPO . . . . . $840.00 ☐ International Preliminary Examination Fee paid to USPTO *(37 CFR 1.482)* . . . . . $670.00 ☐ No International Preliminary Examination Fee paid to USPTO *(37 CFR 1.482)* but International Search Fee paid to USPTO *(37 CFR 1.445(a)(2))* . . . . . $690.00 ☐ Neither International Preliminary Examination Fee *(37 CFR 1.482)* nor International Search Fee *(37 CFR 1.445(a)(2))* paid to USPTO . . . . . $970.00 ☐ International Preliminary Examination Fee paid to USPTO *(37 CFR 1.482)* and all claims satisfied provisions of PCT Article 33(1)-(4) $96.00			
ENTER APPROPRIATE BASIC FEE AMOUNT		**$ 840.00**	
Surcharge of **$130.00** for furnishing the oath or declaration later than ☐ 20 ☐ 30 months from the earliest claimed priority date *(37 CFR 1.492(e))*.			

CLAIMS	NUMBER FILED	NUMBER EXTRA	RATE		
Total Claims	23 -20 =	3	× $18.00	$ 54.00	
Independent Claims	1 -3 =		× $78.00		
Multiple Dependent Claims (if applicable)			+ $260.00		
TOTAL OF ABOVE CALCULATIONS				**$ 894.00**	
Reduction by ½ for filing by small entity, if applicable. Verified Small Entity Statements must also be filed (Note *37 CFR 1.9, 1.27, 1.28)*					
SUBTOTAL				**$ 894.00**	
Processing fee of **$130.00** for furnishing the English translation later than ☐ 20 ☐ 30 months from the earliest claimed priority date *(37 CFR 1.492(f))*.					
TOTAL NATIONAL FEE				**$ 840.00**	
Fee for recording the enclosed assignment *(37 CFR 1.21(h))*. The assignment must be accompanied by an appropriate cover sheet *(37 CFR 3.28, 3.31)*. $40.00 per property.					
TOTAL FEES ENCLOSED				**$ 894.00**	
Amount to be:				Refunded:	
				Charged:	

a. ☒ A check in the amount of **$894.00** to cover the fees is enclosed.

b. ☐ Please charge my **Deposit Account Number 02-0200** in the amount of $ _____ to cover the above fees. A duplicate copy of this sheet is enclosed.

c. ☒ The Commissioner is hereby authorized to charge any additional fees which may be required, or credit any overpayment to **Deposit Account Number 02-0200**. A duplicate copy of this sheet is enclosed.

Note: Where an appropriate time limit under *37 CFR 1.494* or *1.495* has not been met, a petition to revive *(37 CFR 1.137(a) or (b))* must be filed and granted to restore the application to pending status.

BACON & THOMAS, PLLC
625 SLATERS LANE - FOURTH FLOOR
ALEXANDRIA, VIRGINIA 223124-1176
(703) 683-0500

DATE: 02 March 2001

Respectfully submitted,

J. ERNEST KENNEY
Attorney for Applicant
Registration Number: 19,179

PATENT

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

International Patent Application
No. PCT/EP99/06027

PCT/DO/EO/US

International Filing Date: 17 August 1999

Applicant: Heinz HORNUNG et al.

For: METHOD AND DEVICE FOR CONTROLLING PAPER DOCUMENTS OF VALUE

PRELIMINARY AMENDMENT

Commissioner for Patents
Washington, D.C. 20231

Sir:

This paper accompanies documents submitted to establish the U.S. national stage of the above-identified international patent application.

The international patent application was amended under PCT Article 34 and the translation of amended claims 1 and 16 are annexed to the International Preliminary Examination Report (IPER).

Before calculation of the filing fee and before examination, kindly amend the claims as follows:

IN THE CLAIMS:

Cancel all claims without prejudice or disclaimer and substitute therefor new claims 24 - 46 as presented on the appended Appendix of Amended Claims.

REMARKS

All rights are reserved to the original claimed subject matter. The claims have been amended to reduce the filing fees and to better conform to U.S. claim format. Examination of the application as amended is respectfully requested.

Respectfully submitted,
BACON & THOMAS, PLLC

J. ERNEST KENNEY
Attorney for Applicant
Registration Number 19,179

BACON & THOMAS, PLLC
625 Slaters Lane, Fourth Floor
Alexandria, Virginia 22314

Telephone: (703) 683-0500
Facsimile: (703) 683-1080

Date: March 2, 2001

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APPENDIX OF CLAIMS

24. A method for testing a paper of value (1), in particular a bank note, comprising the steps of:

a) irradiating a paper of value (1) located in a measuring plane (2) in first and second areas, the second area being identical, in overlap or adjacent with the first area,

b) detecting the radiation transmitted through the paper of value in the bright field in the first area by means of a detector located in the direct radiation range of the radiation source,

c) detecting the radiation transmitted through the paper of value in the dark field in the second area by means of a detector located outside the direct radiation path of the radiation source,

d) repeating steps a) to c) with respect to other first and second areas of the paper of value,

e) evaluating the transmitted radiation detected in the first and second areas, and

f) comparing the evaluation results of the particular detected first and second areas for ascertaining whether paper-of-value material is present in said areas.

25. The method according to claim 24, wherein detection and evaluation of the radiation transmitted in the dark field are effected separately in time and detection and evaluation of the radiation transmitted in the bright field are likewise effected separately in time.

26. The method according to claim 24, wherein the paper of value is moved translationally over a predetermined distance in the measuring plane for the total duration of detection and evaluation of the radiation transmitted in the dark field and that transmitted in the bright field.

27. The method according to claim 26, wherein the distance is about 2 mm.

28. The method according to claim 26, wherein the translational motion of the paper of value is continuous.

29. The method according to claim 26, wherein the translational motion of the paper of value is effected after irradiation of the areas.

30. The method according to claim 29, wherein evaluation of the detected radiation is effected during the translational motion of the paper of value.

31. The method according to claim 24, wherein irradiation of the first area of the paper of value is effected with a first radiation source (6) and irradiation of the second area of the paper of value with a second radiation source (5).

32. The method according to claim 31, wherein detection of the radiation of the first irradiated area transmitted in the dark field and the radiation of the second irradiated area transmitted in the bright field is effected with a time shift by means of a common detector (7).

33. The method according to claim 32, wherein the second radiation source (5) is directed onto the detector (7) directly and the first radiation source (6) is aligned obliquely thereto so as to irradiate the paper of value (1) at the intersection point of the measuring plane (2) with the connecting line between the detector (7) and the second radiation source (5).

34. The method according to claim 31, wherein at least one of the two radiation sources (5, 6) is an IR light source.

35. The method according to claim 31, wherein at least one of the two radiation sources (5, 6) emits visible light the light reflected by the paper of value (1) being detected and compared with a reference value.

36. The method according to claim 24, within detection of the radiation transmitted in the first area is effected with a first detector (7) and detection of the radiation transmitted in the second irradiated area with a second detector (8).

37. The method according to claim 36, wherein irradiation of the first and second areas of the paper of value is effected by means of a common radiation source (6), the detection of the radiation transmitted through the paper of value in the first area and the radiation transmitted through the paper of value in the second area being effected substantially synchronously.

38. The method according to claim 37, wherein the second detector (8) is directed onto the radiation source (6) directly and the first detector (7) is aligned obliquely thereto so as to detect the paper of value at the intersection point of the measuring plane (2) with the connecting line between the second detector (8) and the radiation source (6).

39. An apparatus for carrying out the method according to claim 1, comprising:

a measuring plane (2),

a device for translationally moving a paper of value (1) in the measuring plane,

at least one radiation sources (5, 6) for irradiating the paper of value located in the measuring plane in first and second areas, the second area being identical in overlap or adjacent with the first area, and

a detector (7, 8) disposed in the direct radiation range for detecting the radiation transmitted from the radiation source through the paper of value in the first irradiated area of the measuring plane (2) in the bright field, characterized by a detector (7) disposed outside the direct radiation output for detecting the radiation transmitted

through the paper of value in the second irradiated area of the measuring plane in the dark field, and an evaluation unit (20) for evaluating the transmitted radiation detected in the first and second areas and for comparing the evaluation results.

40. The apparatus according to claim 39, further comprising:

a first radiation source (6) for irradiating the first area and a second radiation source (5) for irradiating the second area of the measuring plane,

a common detector (7) for detecting both the radiation transmitted through the paper of value in the first irradiated area and the radiation from the second radiation source (5) transmitted through the paper of value 'in the second irradiated area, and

a control device for time-shifted detection of the first and second irradiated areas of the measuring plane (2).

41. The apparatus according to claim 40, wherein the second radiation source (5) is directed onto the common detector (7) directly and the first radiation source (6) is aligned obliquely thereto so as to irradiate the measuring plane (2) at the intersection point of the measuring plane (2) with the connecting line between the common detector (7) and the second radiation source (5).

42. The apparatus according to claim 39, wherein one of the two radiation sources (5, 6) is an IR light source.

43. The apparatus according to claim 42, wherein the other of the two radiation sources (5, 6) emits visible light, and the apparatus furthermore has a reflectance sensor (13) for detecting light reflected by a paper of value (1) located in the measuring plane (2), and an evaluation unit (20) is provided for evaluating the detected reflected light and comparing the evaluation result with a reference value.

44. The apparatus according to claim 39, further comprising:

a common radiation source (6) for irradiating the first and second areas of the measuring plane (2), and

a first detector (7) for detecting the radiation transmitted through the paper of value in the first irradiated area and a second detector (8) for detecting the radiation transmitted through the paper of value in the second irradiated area.

45. The apparatus according to claim 44, wherein a control device is provided for time-shifted detection or irradiation of the radiation transmitted in the first irradiated area and the radiation transmitted in the second irradiated area.

46. The apparatus according to claim 45, wherein the second detector (8) is directed onto the radiation source (6) directly and the first detector (7) is aligned obliquely thereto so as to detect the measuring plane (2) at the intersection point of the measuring plane (2) with the connecting line between the second detector (8) and the radiation source (6).

Method and apparatus for testing papers of value

This invention relates to a method for testing papers of value, in particular bank notes, and to an apparatus for carrying out the method having a measuring plane, a device for translationally moving a paper of value in the measuring plane, at least one radiation source for irradiating first and second areas of the measuring plane and a detector disposed in the dark field with respect to a radiation source for detecting the radiation diffusely transmitted by a paper of value in the first irradiated area of the measuring plane.

Numerous methods and apparatuses for testing papers of value are known. The test itself can be directed to so-called authenticity features of the papers of value, on the one hand, and to the condition of the papers of value, on the other hand. In particular the latter test is applied in connection with used bank notes since they are subject to greater wear as a result of their continuous use. Depending on the nature and extent of the wear the notes are withdrawn and replaced by newly issued notes. Features used for assessing the condition of bank notes are e.g. holes, tears, missing parts, dog-ears, dirt and stains on the notes. In contrast, the notes can be tested for authenticity e.g. in terms of IR-transmitting or IR-absorbent ink prints, dimensions such as length and width, colorfastness, printed image, opacity and the like. Some apparatuses also provide for combined testing of condition and authenticity features.

GB-A-2 107 911 discloses an apparatus for testing bank notes which evaluates solely the authenticity of a note both by an optical test relating to color reflectance and IR opacity and by a length test. The note is moved along a measuring plane and scanned along three lines in order to determine IR opacity and color reflectance. Opacity measurement is done by irradiating the note with light in the infrared wave range and detecting the IR radiation transmitted through the note by means of a detector disposed "in the bright field." Bright-field measurement means that the detector is reached directly by radiation from the radiation source if no note is present, and if a note is in the measuring plane it detects the radiation transmitted through the note directly from the radiation source (bright-field measurement). For measuring color reflectance a radiation in the visible wave range is additionally directed to the

surface of the note, and the radiation reflected by the note surface is detected with a reflectance sensor. The detected transmission and reflectance radiations are compared with reference values in order to test the authenticity of the note. Testing of the length of the note is likewise done by means of the IR radiation source in that the leading edge of the note is detected therewith when the note is supplied to the measuring station while the end of the note is determined by a second sensor. However, there is no condition testing of the note.

DE-A-196 04 856 discloses an apparatus and method for testing optical security features with metallically reflecting layers such as holograms and the like as to exact positioning in the note, edge form (fraying of the contour) and completeness (holes, missing parts). One thus tests the condition of said security features in bank notes returning from circulation to the bank for example. The condition test of said metallic security features is done in transmitted light, similarly to the above-described opacity test. However, bright-field measurement as described above has proved unsuitable since an opposite arrangement of radiation source and detector would lead to metrologically adverse overdriving of the detector through direct incidence of radiation in the spaces between consecutive notes. Holes in the material under measurement would have the same effect. DE-A-196 04 856 accordingly proposes dark-field measurement. In dark-field measurement the detector is aligned with the radiation source so as not to receive any direct radiation from the radiation source when no note is present, but to be reached substantially only by radiation from the radiation source when a note is present, the radiation transmitted through the note being detected. Accordingly the detector is disposed with respect to the transport plane of the note so that light passing through the bank-note paper beside the metal layer or through its being damaged (holes, abrasion in the area of folds) is only measured insofar as it is scattered by the paper. However, this method cannot determine holes or other flaws in the paper but only in the metallic coating. Furthermore, dark-field measurement is unsuitable for determining a flaw in the paper itself since the detector cannot clearly ascertain e.g. in the case of a hole whether it is an especially opaque and therefore nontransparent place in the note or in fact a

hole in the note since the detector disposed in the dark field would receive no radiation either way.

EP 0 537 513 A1 describes an improved authenticity tester for bank notes which is intended to recognize even especially good forgeries. The device is accordingly elaborate and it is proposed that dark-field measurements be performed both with IR radiation and with red light, on the one hand, and reflectance measurements both with respect to the reflectance of red irradiated light and with respect to the reflectance of green irradiated light, on the other hand. The quality of authenticity testing is thus increased by a plurality of independent authenticity tests being performed. No condition testing of the note is performed with this device.

DE-PS 20 37 755 discloses an apparatus for testing vouchers which reliably tests the authenticity of bank notes containing fluorescent fibers. The note is exposed on one side to radiation exciting the fluorescent substances, and the resulting fluorescent radiation emitted by the note is detected on both sides of the note. The detectors for fluorescent radiation are disposed in the dark field with respect to the excitation radiation source so that a further detector can be disposed in the bright field on the side of the note opposite the excitation radiation source. The detector disposed in the bright field is intended to recognize the condition of the paper of value by recognizing deficient paper density, splices, tears, inaccurate interfaces, faulty watermarks and lacking security threads by the opacity of the paper. However, this also involves the problem that direct incidence of light on the detector disposed in the bright field can lead to overdriving of the detector. In particular this detector arrangement does not permit reliable differentiation between relatively transparent, e.g. thin or unprinted, paper and holes.

The aforementioned apparatuses are either fully unsuitable for condition testing of papers of value because they relate only to authenticity testing, or only partly suitable because they cannot reliably determine holes, tears, missing parts, dog-ears and the like. Dark-field measurement involves the problem of the detector failing to determine a measured value both when detecting a flaw and when detecting a very opaque area so that it is impossible to differentiate between a hole and high opacity. In bright-field measurement the detection of a hole leads to overdriving of the detec-

tor or at least to a high measured value which cannot be reliably distinguished from a likewise high value from a very weakly opaque area of the note.

For this reason one customarily determines flaws in bank notes using a separate hole detector, usually designed as an ultrasonic sensor. This additional hole detector involves additional costs which are not justifiable in every case. Thus, a bank note testing device detecting the condition of the notes and optionally easily testable authenticity features would frequently be sufficient for use in small banks, exchange bureaus, casinos and the like.

The problem of the present invention is therefore to propose a method and an apparatus for testing papers of value which permit reliable recognition of flaws in bank notes in an inexpensive way.

This problem is solved by a method and an apparatus according to independent claims 1 and 16.

According to the invention the opacity of a note is measured both in the bright and dark fields and the determined measured values are compared. Since neither bright-field measurement nor dark-field measurement taken alone permits a reliable statement about a flaw in the note, the inventive solution provides for comparison of the two values in order to recognize whether a flaw or a slightly opaque or highly opaque area of the note is involved. When a slightly opaque area of the note is detected, bright-field measurement states no meaningful value but dark-field measurement is clear. When a highly opaque area of the note is detected, however, dark-field measurement states no meaningful value but bright-field measurement is clear.

This principle constitutes a comparatively inexpensive solution in particular because the transmission measurement method (bright-field or dark-field) customarily used for testing the opacity of bank notes need not be equipped with an additional ultrasonic sensor as a hole detector, but instead a further transmission measurement (dark-field or bright-field) is effected so that one can omit for example a special evaluation unit for the ultrasonic sensor. Due to the duplication of several components, such a tester is much less expensive to produce as a mass-produced article.

The test result is exacter the better the resolving power, i.e. the smaller the distances between detected bank note areas and the higher the degree of overlap of the

note areas measured in the bright field and those measured in the dark field. An optimum result is obtained when the note areas measured in the bright field and the note areas measured in the dark field are identical and the total note is tested in extremely small steps. The method can be considerably accelerated when adjacent note areas are measured alternately in the bright and dark fields. However, this only permits reliable detection of flaws in the bank note which are so great that they are detected both by bright-field measurement and by dark-field measurement.

This principle can be realized in different ways in terms of procedure and apparatus. Thus, one radiation source and one detector can be used for bright-field measurement and dark-field measurement in each case. However, a cost reduction can be obtained by using instead of one detector and radiation source for bright-field measurement and dark-field measurement in each case, i.e. instead of two detectors and two radiation sources, either only one common radiation source with two detectors or one common detector with two radiation sources.

Using one common radiation source with two detectors, there are two possibilities. Either the radiation source irradiates two separate areas of the measuring plane, the first detector being disposed in the dark field of one irradiated area and the second detector in the bright field of the other area, or the radiation source irradiates only one area of the measuring plane, the first detector being disposed in the dark field of said irradiated area and the second detector in the bright field thereof.

Using one common detector with two radiation sources, there are likewise two possibilities, since the two sources can irradiate either two different areas of the measuring plane or the same area of the plane, the sources being disposed in both cases so that the common detector is in the dark field with respect to the first source and in the bright field with respect to the second source. Furthermore, the embodiment with one common detector necessitates that bright-field and dark-field measurement be performed at separate times. This can be obtained by driving the radiation sources accordingly or, in case two different areas of the note are irradiated, by darkening the detector with respect to a certain area in each case, or by aligning the detector with a certain area in each case. It is most favorable procedurally to drive the first and second radiation sources separately.

A special embodiment of the invention provides that at least one radiation source is designed as an IR radiation source. This permits simultaneous testing of the note for IR permeability since many notes are printed with special inks which either absorb IR radiation or, more frequently, are permeable to IR radiation.

The embodiment with two separate radiation sources furthermore offers the possibility of additional reflectance measurement since a reflectance receiver on the side of the radiation sources can be used to test the printed image of a note by the light reflected by the note. Further advantages and properties of the inventive solution will become clear from the following description and reference to the figures.

Figure 1 shows a preferred embodiment of an inventive apparatus as a schematic diagram.

Figures 2a to 2e show five different embodiments of the invention as schematic diagrams.

Figure 3 shows a cross section of the apparatus of Figure 1 along III-III.

Figure 4 shows a clock diagram for detecting a bank note and evaluating the detected results.

Figures 1 and 3 schematically show a preferred embodiment of the present invention, Figure 3 showing a cross section along line III-III of the apparatus shown in Figure 1. Bank note 1 is moved along measuring plane 2 between upper window 3 and lower window 4. Below window 4 two LED arrays with LEDs 5 and 6 are so disposed that each LED irradiates the measuring plane in a defined area. The radiation paths of LEDs 5 and 6 are indicated with dashed lines. Above window 3 an array of detectors 7 is so disposed that each detector 7 is in the direct radiation range of LEDs 5. Detectors 7 are thus in the bright field with respect to LEDs 5. With respect to LEDs 6 the arrangement of detectors 7 is selected so that the detectors are not irradiated directly by LEDs 6. Detectors 7 are thus in the dark field with respect to LEDs 6. Detectors 7 are aligned so as to detect the defined areas on the bank note irradiated by opposite LEDs 5 and 6. That is, detector 7 detects radiation from directly opposite LEDs 5 transmitted through note 1 in the bright field, on the one hand, and radiation from obliquely opposite LEDs 6 transmitted through the note in the dark field, on the other hand.

Before the transmitted radiation reaches the detector it can be focused by means of simple radiation collimator 10. A simple Selfoc array may suffice. The invention can also be executed without any focusing of the transmitted radiation, however, if the transmitted radiation of the area to be tested is directed onto the detector by channeling.

Evaluation unit 20 is connected to detector 7 for evaluating the detected radiation values and determining by comparison of the values from bright-field measurement with the values from dark-field measurement whether the detected area of the note might have a flaw such as a hole, tear, etc.

Since the LED arrays and the detector array detect the total width of a note to be detected and since the note is moved between the LED arrays and the detector array along measuring plane 2, the total note can be successively tested for flaws. Comparison of bright- and dark-field measurements at the same time permits recognition of the outside contours of a note, so that the length and width of notes can be determined relatively exactly.

The resolving power depends of course on the number of measurements across the width and along the length of the note. This is especially clear in Figure 3 where the radiation paths of LEDs 5 and detection ranges of detectors 7 are shown by dashed lines. Note 1 located in measuring plane 2 interrupts only the light path of the third (from the left) to the second last LEDs 5. Evaluation of the bright-field and dark-field measured values provided by the first and second (from the left) and last detectors 7 will therefore lead to the result "flaw" over the total length of the tested note, from which it can be inferred that the outer edges of the note are in the range of the third and second last detectors. Deviating from the view of Figure 3, sixty detectors are preferably disposed across the width as a detector array, whereby each detector can have two sensitive pixels. The detector array can have gaps between the detectors and pixels, permitting detectors to be omitted. This affects the resolving power of the total apparatus. However, a resolution of 1 mm transversely to the transport direction may be sufficient for simple purposes.

For example, the two outer detectors of the sixty can be disposed beside the actual measuring area for bank-note testing. They can then be used e.g. to form a reference value for the brightness of the radiation emitted by the LEDs.

Preferably, the LEDs of at least one LED array radiate IR light to permit detection of authenticity features, i.e. the presence of IR-transmitting or IR-absorbent prints. Since IR-absorbent inks are used less often than IR-transmitting inks, LEDs 6, i.e. the radiation source for dark-field illumination, are preferably selected as an IR radiation source. This reduces the probability of a highly IR-absorbent printed image being evaluated as a flaw.

Advantageously, the second LED array, i.e. LEDs 5 here, radiate light in the visible wave range. By a reflectance measurement of radiation 12 reflected by the surface of a note one can additionally recognize the printed image and/or denomination of the note by means of reflectance sensor 13. Red-light LEDs are preferably used for this purpose.

Figures 2a to 2e show basic embodiments of the invention described above with reference to an especially preferred embodiment. Figure 2b shows the especially preferred embodiment described above with respect to Figure 1, wherein two light sources 5 and 6 illuminate a common defined area of measuring plane 2 and have associated therewith single detector 7 disposed on the opposite side of plane 2 which detects both radiation from red-light source 5 transmitted in the bright field and IR radiation from source 6 transmitted in the dark field.

Figure 2a shows a similar structure to Fig. 2b with two radiation sources 5 and 6 and common detector 7. However, source 6 illuminates a first area of the measuring plane and source 5 a second area of measuring plane 2, and the detector detects radiation from source 5 transmitted in the bright field and radiation from source 6 transmitted in the dark field. The first and second irradiated areas of the measuring plane can fundamentally also overlap.

The embodiments shown in Figures 2a and 2b presuppose, because of the use of only one detector, that detector 7 detects radiation transmitted in the bright field and radiation transmitted in the dark field independently of one other, i.e. with a time shift, so that comparison can be performed in evaluation unit 20 for ascertain-

ing flaws of the notes with reference to the separately detected bright-field and dark-field measured values. Time-shifted detection is preferably obtained by time-shifted irradiation of the first and second areas. However, it is fundamentally also possible that the detector is shielded intermittently from the first area and intermittently from the second. Furthermore, it is conceivable that the detector is directed intermittently only onto the first area and intermittently only onto the second.

A special advantage consists in the use of two different kinds of radiation. For example the radiation sources can differ in the color spectrum, e.g. emit IR radiation and visible light.

Figures 2c and 2d show embodiments with a reversal of the above-described principle. Instead of two radiation sources and a common detector, these embodiments provide for a common radiation source and two detectors. In Figure 2c radiation source 6 illuminates a defined area of measuring plane 2 onto which both detector 7 disposed in the dark field and detector 8 disposed in the bright field are directed. In Figure 2d, on the other hand, two different areas of measuring plane 2 are illuminated by radiation source 6 since e.g. the remaining radiation from source 6 is shielded by shield 9. Detector 7 is disposed in the dark field with respect to the first irradiated area while detector 8 is disposed in the bright field with respect to the second irradiated area.

The advantage of the arrangements according to Figures 2c and 2d with two detectors is that bright-field measurement and dark-field measurement can be performed synchronously. However, the use of radiations of different wavelengths is not possible as in the arrangements of Figs. 2a and 2b.

For simple evaluation it is advantageous if only one area of measuring plane 2 is illuminated, as shown in Figures 2b and 2c, since in this case the evaluation of the measuring results of bright-field measurement and dark-field measurement of corresponding areas can be effected immediately.

Figure 2e shows a further but more elaborate and therefore less interesting embodiment of the present invention wherein first detector 7 is disposed in the dark field of first radiation source 6 and second detector 8 in the bright field of second radiation source 5. Although this embodiment is more elaborate than those described

above, it offers the advantages of using two radiation sources and two detectors, i.e. synchronous measurement in the bright and dark fields and the use of different wavelengths.

The inventive method shall be described in the following. Referring to Figure 1, note 1 is supplied along measuring plane 2 between the two windows 3 and 4 to a measuring area, i.e. the area detected with detectors 7. Each detector 7 defines its own measuring area. The leading edge of a note is then determined by means of one of the two radiation sources, preferably by dark-field measurement by means of radiation source 6 since the edge area of bank notes is usually not completely opaque so that determination of the leading edge of the note is reliably possible by means of dark-field measurement. Radiation source 5 is meanwhile turned off or shielded in order not to influence the measuring result of the dark-field measurement.

The radiation from dark-field source 6 transmitted through note 1 in a first area is detected by detector 7. After a predetermined detection time has passed, the detected radiation is read out by an evaluation unit. For readout, detector 7 is inaccessible for reception of further radiation since e.g. radiation source 6 is turned off or shielded.

After readout of the radiation transmitted from source 6 through note 1 in the first area the note is illuminated in a second area by means of source 5 while source 6 is shielded or preferably turned off. First and second areas of the note can be identical in extreme cases but also overlap - e.g. 50 percent in each case - or be completely side by side. Radiation transmitted through the note in the second area is detected by detector 7. Then the transmitted radiation detected by detector 7 in the second area is read out. This process is repeated until the total note has been detected area by area.

In the embodiment shown in Figure 1 the second area of the note irradiated by source 5 is located in the same area of measuring plane 2 which was also illuminated by source 6. However, this does not mean that the irradiated areas of the note are identical. Only in the case of accordingly clocked feed motion of note 1 within measuring plane 2 do the note areas irradiated by source 5 coincide identically with the note areas previously irradiated by source 6. For example, the motion of the note

can be effected in two stages at a time, the note being moved only between bright-field and dark-field measurements and the measured radiation read out during the note feed.

With continuous feed motion of note 1, however, the second area of note 1 irradiated by source 5 is slightly offset from the first note area illuminated by source 6. This has to do with the time sequence of irradiation and the motion of the note. Depending on the transport speed of a continuously moved note and the time control of irradiation by means of sources 5 and 6, the first areas of note 1 illuminated by source 6 and the second areas thereof illuminated by source 5 can thus overlap more or less or even be side by side. The further apart the first and second irradiated note areas are, the lower the resolution of the test apparatus will be and the greater the flaws of the note which are recognizable with the test apparatus.

Figure 4 shows by way of example a time history of the irradiation of note 1 with sources 5 and 6 and the intermediate time for reading out the detected radiation over a time axis. According to uppermost curve *a* the note is first irradiated for 170 µs with dark-field light source 6. After irradiation the transmitted radiation detected by detector 7 in the first area is read out for a time period of likewise 170 µs, as shown in graph *b*. At the end of the readout process a time gap of about 30 µs is provided before irradiation of a second area of note 1 in order to ensure that the readout of the detector is completed before new irradiation. Irradiation of the second area of note 1 by means of source 5 is likewise effected for a time period of 170 µs, as shown in graph *c*. This is followed by a readout of the transmitted radiation detected by detector 7 in the bright field for another 170 µs, and then by a further safety window of 30 µs. A next first area of the note is then measured in the dark field again, as indicated in curve *a*. A complete measuring cycle thus lasts e.g. 740 µs.

The above-described time history is especially advantageous because it permits the use of inexpensive detectors 7 which have enough time to discharge during the read time so that they are available for detecting the transmitted radiation of the next note area. More elaborate systems would obviously permit simultaneous detection, readout and adding up of the detected transmitted radiation so that the necessary

time period for evaluating detected radiation could be omitted. This reduces the test time but considerably increases the equipment expense.

For the purposes of testing the condition of bank notes in circulation it has turned out that a sufficient resolution is achieved, with note 1 moved continuously in measuring plane 2 and temporally successive bright-field and dark-field measurement, when the note is moved over a transport path of 2 mm with the total cycle lasting e.g. 740 µs as shown in Figure 4. It is evident that only a resolution of e.g. at most 2 mm is thereby reached since in the case of flaws with dimensions therebelow neither bright-field measurement nor dark-field measurement provides a clear value indicating the presence of bank-note material.

The inventive method permits reliable detection of holes, tears, missing parts, dog-ears and the like which are within the resolution range of the apparatus by comparing the transmission radiation values measured in the dark field of the first note area and in the bright field of the second note area. If the value measured in the bright field is above a given limiting value which indicates either thin unprinted paper or a flaw in the paper, it is ascertained by comparison with the value of the second area measured in the dark field that it is actually a flaw if dark-field measurement yielded a measured value near zero. If dark-field measurement yielded a relatively high value, however, this is a sign that there was actually thin unprinted paper in the measuring plane.

Evaluation of the values measured in the bright and dark fields can be effected immediately after readout of the measured values so that a statement about flaws is possible right away with reference to comparison of said values. However, the read out measured values can also be first stored temporarily and evaluated at the end of testing of the note. Besides the ascertainment of flaws, one can then simultaneously perform an authenticity comparison with reference data of standard bank notes stored in an EEPROM.

For such additional authenticity recognition, the inventive method provides as a further embodiment that one of the light sources, preferably the dark-field measurement light source, emits radiation in the IR wave range. This permits detection of images printed with IR ink. Such inks can be both permeable and absorbent for IR

light while being simultaneously impermeable when illuminated with red light, so that evaluation of the detected transmitted IR radiation makes it possible to infer the authenticity of the note. The other of the two radiation sources can emit instead of IR radiation a radiation in the visible wave range, e.g. pure red light. Evaluation of the detected red radiation transmitted makes it possible to infer the printed image and the denomination. With reference to the denomination one can in turn infer the length and width dimensions of the note, so that one can perform not only a test of the IR printed image via the dimensions of the note determined with the inventive method but also a further authenticity test, i.e. the test of whether the dimensions of the tested note match the detected denomination.

By means of reflectance sensor 13 additionally provided, one can check the colorfastness, printed image and IR reflecting properties of note 1 with reference to light 12 reflected by the irradiated note area. In an evaluation unit the measured reflectance values are compared with reference values of standard bank notes.

The above-described procedure can be performed both in the basic embodiment according to Figure 1 or 2b and in the embodiment according to Figure 2a. The above-described method can also be performed in corresponding fashion with the embodiments of the inventive apparatus shown in Figures 2c and 2d, these offering the advantage of permitting simultaneous evaluation of dark-field measurement and bright-field measurement due to the use of two detectors 7 and 8. The test speed can thus be doubled since only one time segment is necessary for detecting radiation transmitted in the bright and dark fields and for reading out the detected transmitted radiation, so that the total cycle is 370 µs, including a safety window of 30 µs. However, this embodiment has the disadvantage that only one radiation can be used.

The embodiment according to Figure 2e offers the procedural advantages of the basic embodiments shown in Figures 2c and 2d, and furthermore permits one of the two radiation sources to be designed as a source emitting visible light.

Patent claims

1. A method for testing a paper of value (1), in particular a bank note, comprising the steps of
   a) irradiating a paper of value (1) located in a measuring plane (2) in a first area (dark field) and in a second area (bright field), the second area being identical, in overlap or adjacent with the first area,
   b) detecting the radiation transmitted through the paper of value in the first area,
   c) detecting the radiation transmitted through the paper of value in the second area,
   d) repeating steps a) to c) with respect to other first and second areas of the paper of value,
   e) evaluating the transmitted radiation detected in the first and second areas, and
   f) comparing the evaluation results of the particular detected first and second areas for ascertaining whether paper-of-value material is present in said areas.
2. A method according to claim 1, characterized in that detection and evaluation of the radiation transmitted in the dark field are effected separately in time and detection and evaluation of the radiation transmitted in the bright field are likewise effected separately in time.
3. A method according to claim 1 or 2, characterized in that the paper of value is moved translationally over a predetermined distance in the measuring plane for the total duration of detection and evaluation of the radiation transmitted in the dark field and that transmitted in the bright field.
4. A method according to claim 3, characterized in that the distance is about 2 mm.
5. A method according to claim 3 or 4, characterized in that the translational motion of the paper of value is continuous.

6. A method according to claim 3 or 4, characterized in that the translational motion of the paper of value is effected after irradiation of the areas.
7. A method according to claim 6, characterized in that evaluation of the detected radiation is effected during the translational motion of the paper of value.
8. A method according to any of claims 1 to 7, characterized in that irradiation of the first area of the paper of value is effected with a first radiation source (6) and irradiation of the second area of the paper of value with a second radiation source (5).
9. A method according to claim 8, characterized in that detection of the radiation of the first irradiated area transmitted in the dark field and the radiation of the second irradiated area transmitted in the bright field is effected with a time shift by means of a common detector (7).
10. A method according to claim 9, characterized in that the second radiation source (5) is directed onto the detector (7) directly and the first radiation source (6) is aligned obliquely thereto so as to irradiate the paper of value (1) at the intersection point of the measuring plane (2) with the connecting line between the detector (7) and the second radiation source (5).
11. A method according to any of claims 8 to 10, characterized in that at least one of the two radiation sources (5, 6) is an IR light source.
12. A method according to any of claims 8 to 11, characterized in that at least one of the two radiation sources (5, 6) emits visible light, the light reflected by the paper of value (1) being detected and compared with a reference value.
13. A method according to any of claims 1 to 7, characterized in that detection of the radiation transmitted in the first area is effected with a first detector (7) and detection of the radiation transmitted in the second irradiated area with a second detector (8).
14. A method according to claim 13, characterized in that irradiation of the first and second areas of the paper of value is effected by means of a common radiation source (6), the detection of the radiation transmitted through the paper of value in the first area and the radiation transmitted through the paper of value in the second area being effected substantially synchronously.

15. A method according to claim 14, characterized in that the second detector (8) is directed onto the radiation source (6) directly and the first detector (7) is aligned obliquely thereto so as to detect the paper of value at the intersection point of the measuring plane (2) with the connecting line between the second detector (8) and the radiation source (6).

16. An apparatus for carrying out the method according to any of claims 1 to 15, comprising

- a measuring plane (2),
- a device for translationally moving a paper of value (1) in the measuring plane,
- at least one radiation sources (5, 6) for irradiating the paper of value located in the measuring plane in a first area (dark field) and in a second area (bright field), the second area being identical, in overlap or adjacent with the first area, and
- a detector (7, 8) for detecting the radiation transmitted from the radiation source through the paper of value in the first irradiated area of the measuring plane (2), characterized by
- a detector (7) for detecting the radiation transmitted through the paper of value in the second irradiated area of the measuring plane, and
- an evaluation unit (20) for evaluating the transmitted radiation detected in the first and second areas and for comparing the evaluation results.

17. An apparatus according to claim 16, characterized by

- a first radiation source (6) for irradiating the first area and a second radiation source (5) for irradiating the second area of the measuring plane, and
- a common detector (7) for detecting both the radiation transmitted through the paper of value in the first irradiated area and the radiation from the second radiation source (5) transmitted through the paper of value in the second irradiated area, and
- a control device for time-shifted detection of the first and second irradiated areas of the measuring plane (2).

18. An apparatus according to claim 17, characterized in that the second radiation source (5) is directed onto the common detector (7) directly and the first radiation source (6) is aligned obliquely thereto so as to irradiate the measuring plane (2) at the intersection point of the measuring plane (2) with the connecting line between the common detector (7) and the second radiation source (5).
19. An apparatus according to any of claims 16 to 18, characterized in that one of the two radiation sources (5, 6) is an IR light source.
20. An apparatus according to claim 19, characterized in that the other of the two radiation sources (5, 6) emits visible light, and the apparatus furthermore has a reflectance sensor (13) for detecting light reflected by a paper of value (1) located in the measuring plane (2), and an evaluation unit (20) is provided for evaluating the detected reflected light and comparing the evaluation result with a reference value.
21. An apparatus according to claim 16, characterized by
    - a common radiation source (6) for irradiating the first and second areas of the measuring plane (2), and
    - a first detector (7) for detecting the radiation transmitted through the paper of value in the first irradiated area and a second detector (8) for detecting the radiation transmitted through the paper of value in the second irradiated area.
22. An apparatus according to claim 21, characterized in that a control device is provided for time-shifted detection or irradiation of the radiation transmitted in the first irradiated area and the radiation transmitted in the second irradiated area.
23. An apparatus according to claim 22, characterized in that the second detector (8) is directed onto the radiation source (6) directly and the first detector (7) is aligned obliquely thereto so as to detect the measuring plane (2) at the intersection point of the measuring plane (2) with the connecting line between the second detector (8) and the radiation source (6).

Abstract

A method and apparatus for testing a paper of value, in particular for condition testing of a bank note, are proposed wherein the bank note is subjected both to dark-field measurement and to bright-field measurement. From comparison of the measuring results of dark-field measurement and bright-field measurement one can make a clear statement about whether a flaw, for example a hole, tear, etc., is present in the bank note in the tested area. The bright-field and dark-field measuring devices can be formed separately with one LED array and detector array in each case. However, preferred embodiments provide for either a common LED array with two detectors or two LED arrays with a common detector. If two LED arrays are used, the dark-field radiation source is preferably formed as an IR light source and the bright-field radiation source as a red-light radiation source in order to permit authenticity testing of the paper of value to be performed as well as condition testing thereof. (Fig. 1)

FIG.1

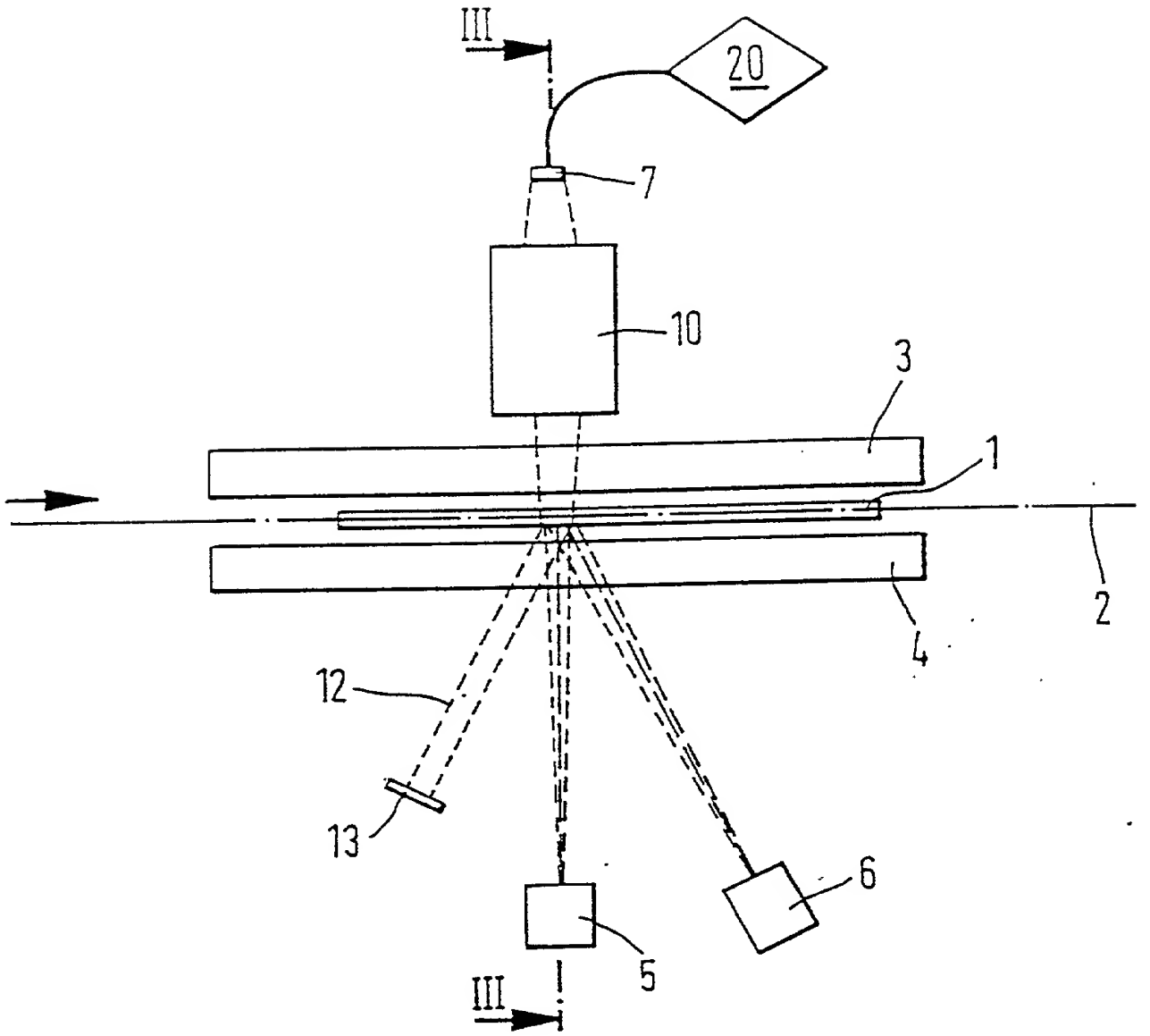


FIG.3

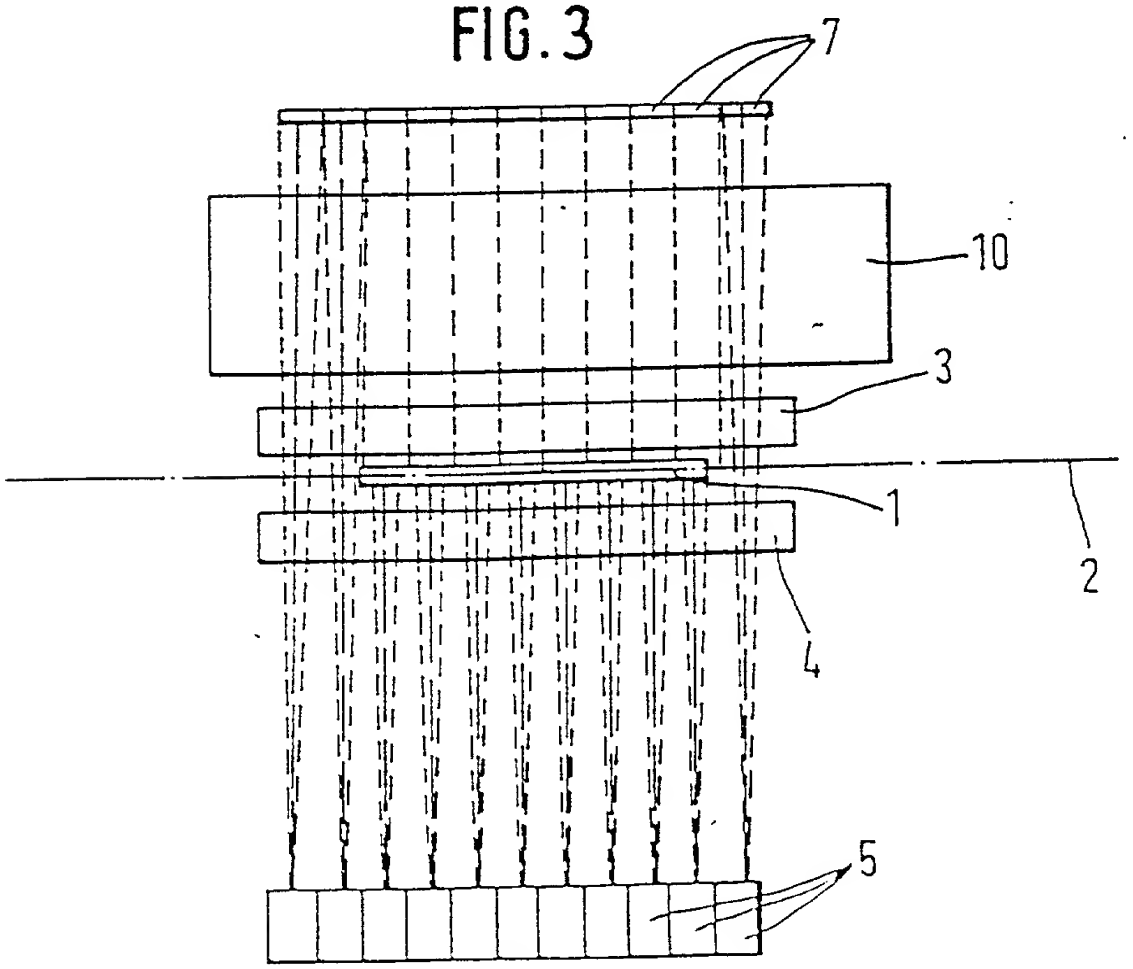


FIG. 2a

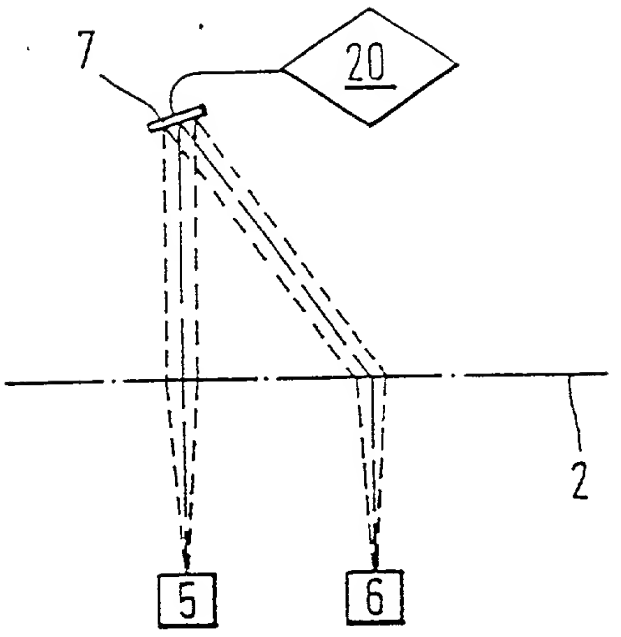


FIG. 2b

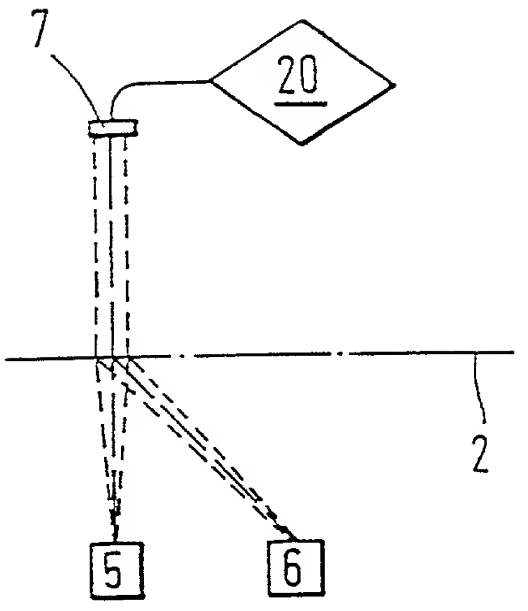


FIG. 2c

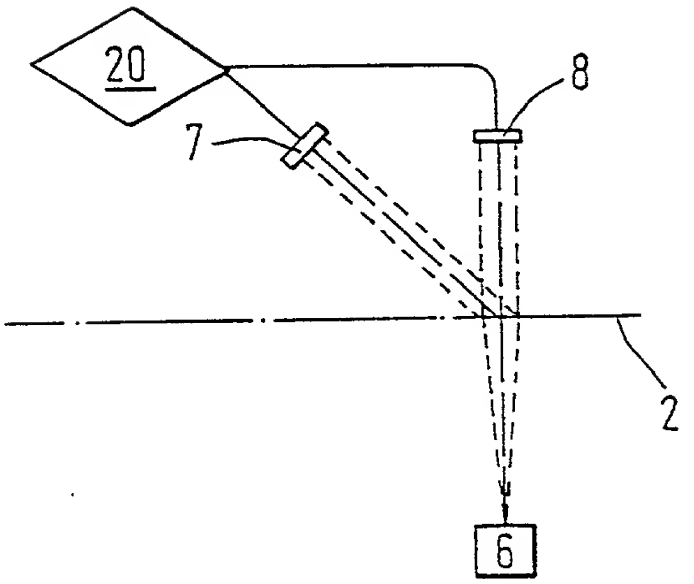


FIG. 2d

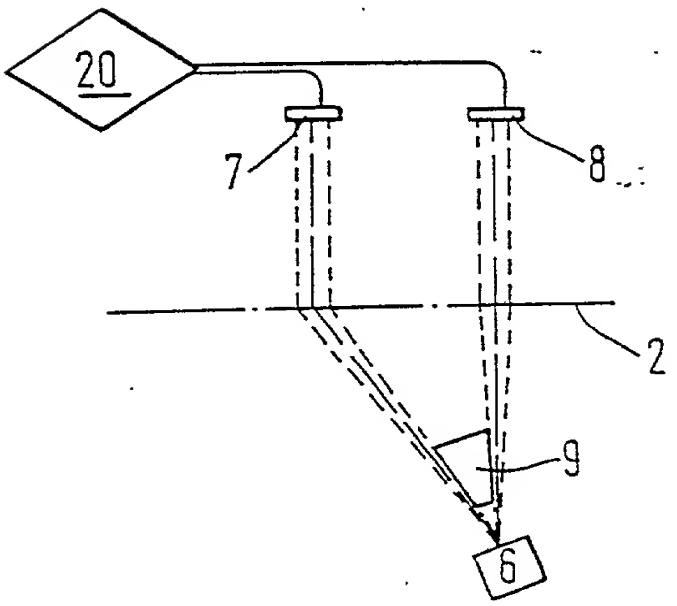


FIG. 2e

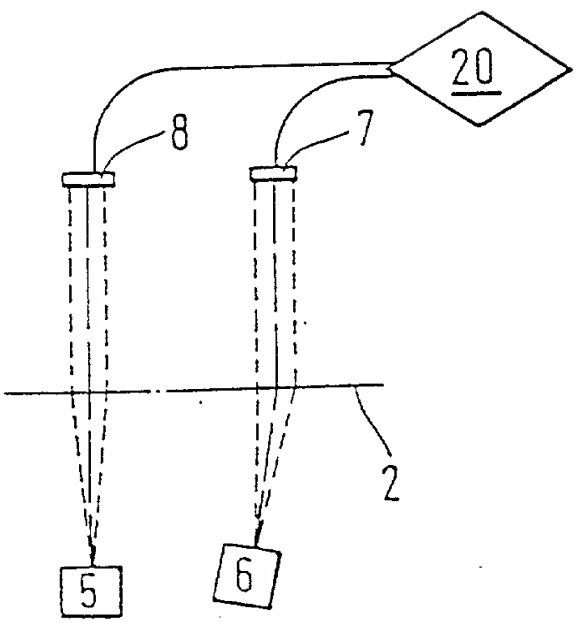
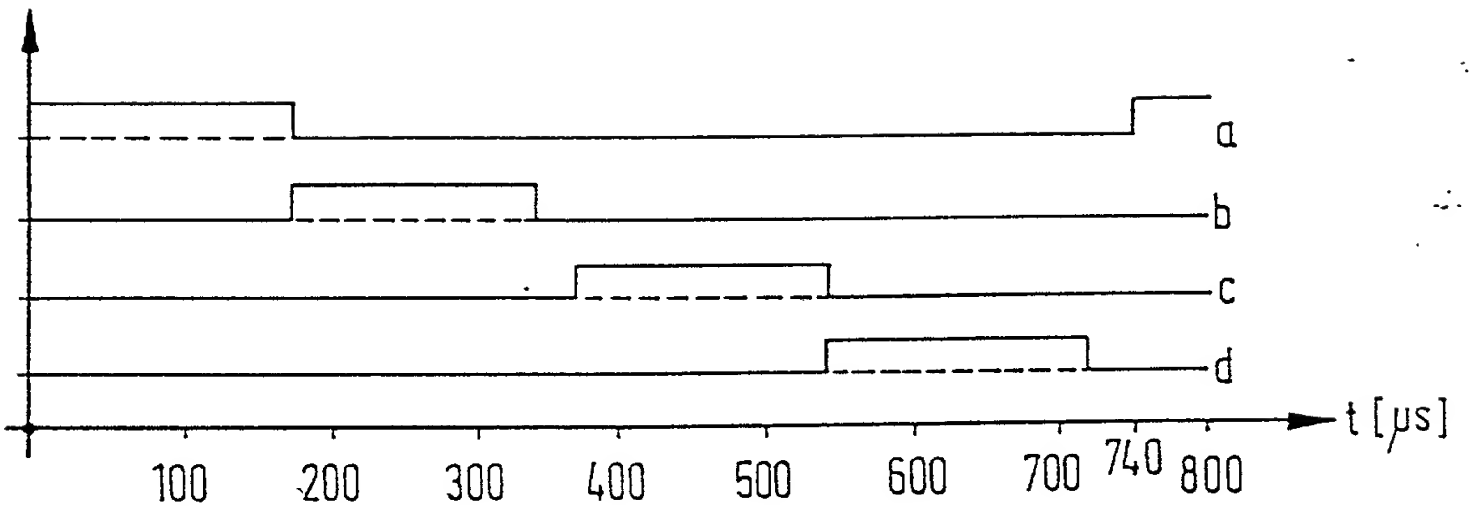


FIG. 4



ANNEX

TO IPER

FOR

PCT/EP99/06027

New patent claims 1 and 16

1. A method for testing a paper of value (1), in particular a bank note, comprising the steps of

a) irradiating a paper of value (1) located in a measuring plane (2) in first and second areas, the second area being identical, in overlap or adjacent with the first area,

b) detecting the radiation transmitted through the paper of value in the bright field in the first area by means of a detector located in the direct radiation range of the radiation source,

c) detecting the radiation transmitted through the paper of value in the dark field in the second area by means of a detector located outside the direct radiation path of the radiation source,

d) repeating steps a) to c) with respect to other first and second areas of the paper of value,

e) evaluating the transmitted radiation detected in the first and second areas, and

f) comparing the evaluation results of the particular detected first and second areas for ascertaining whether paper-of-value material is present in said areas.

16. An apparatus for carrying out the method according to any of claims 1 to 15, comprising

- a measuring plane (2),
- a device for translationally moving a paper of value (1) in the measuring plane,
- at least one radiation sources (5, 6) for irradiating the paper of value located in the measuring plane in first and second areas, the second area being identical, in overlap or adjacent with the first area, and
- a detector (7, 8) disposed in the direct radiation range for detecting the radiation transmitted from the radiation source through the paper of value

in the first irradiated area of the measuring plane (2) in the bright field, characterized by

- a detector (7) disposed outside the direct radiation output for detecting the radiation transmitted through the paper of value in the second irradiated area of the measuring plane in the dark field, and
- an evaluation unit (20) for evaluating the transmitted radiation detected in the first and second areas and for comparing the evaluation results.

ATTORNEY/DOCKET NO. **JEK/Hornung**

DECLARATION FOR PATENT APPLICATION AND APPOINTMENT OF ATTORNEY

As a below named inventor, I hereby declare that my residence, post office address and citizenship are as stated below next to my name; I believe that I am the original, first and sole inventor (if only one name is listed below) or an original, first and joint inventor (if plural names are listed below) of the subject matter which is claimed and for which a patent is sought on the invention (Design, if applicable) entitled:

METHOD AND DEVICE FOR CONTROLLING PAPER DOCUMENTS OF VALUE

the specification of which (check one):

☐ is attached hereto, or ☒ was filed on: **17 August 1999** as U.S. Application Number or PCT International Application Number: **(PCT/EP99/06027) 09/786,195**

and (if applicable) was amended on:

I hereby state that I have reviewed and understand the contents of the above-identified specification, including the claims, as amended by any amendment(s) referred to above. I acknowledge the duty to disclose information which is material to patentability as defined in *Title 37, Code of Federal Regulations, §1.56.* I hereby claim foreign priority benefits under *Title 35, United States Code §119* of any foreign application(s) for patent or inventor's certificate listed below and have also identified below any foreign application for patent or inventor's certificate having a filing date before that of the application on which priority is claimed.

PRIOR FOREIGN APPLICATION(S)			PRIORITY CLAIMED	
Number	**Country**	**Day/Month/Year Filed**	**Yes**	**No**
198 40 482.4	Germany	04 September 1998	X	

☐ Additional Priority Application(s) Listed on Following Page(s)

I HEREBY CLAIM THE BENEFIT UNDER TITLE 35 U.S. CODE §119(E) OF ANY U.S. PROVISIONAL APPLICATIONS LISTED BELOW.	
Application Number	**Day/Month/Year Filed**

☐ Additional Provisional Application(s) Listed on Following Page(s)

I hereby claim the benefit under *Title 35, United States Code, §120* of any United States application(s) or PCT international application(s) designating The United States of America listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in that/those prior application(s) in the manner provided by the first paragraph of *Title 35, United States Code, §112*, I acknowledge the duty to disclose information which is material to patentability as defined in *Title 37, Code of Federal Regulations, §1 56* which became available between the filing date of the prior application(s) and the national or PCT international filing date of this application:

Application Number	**Filing Date**	**Status - Patented, Pending or Abandoned**

☐ Additional US/PCT Priority Application(s) listed on Following Page(s)

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under *section 1001 of title 18 of the United States Code* and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

POWER OF ATTORNEY: I (We) hereby appoint as my (our) attorneys, with full powers of substitution and revocation, to prosecute this application and transact all business in the Patent and Trademark Office connected therewith: J. Ernest Kenney, Reg. No. 19,179; Eugene Mar, Reg. No. 25,893; Richard E. Fichter, Reg. No. 26,382; Thomas J. Moore, Reg. No. 28,974; Joseph DeBenedictis, Reg. No. 28,502; Benjamin E. Urcia, Reg. No. 33,805; and

I(we) authorize my(our) attorneys to accept and follow instructions from **Klunker Schmitt-Nilson and Hirsch** regarding any matter related to the preparation, examination, grant and maintenance of this application, any continuation, continuation-in-part or divisional based thereon, and any patent resulting therefrom, until I(we) or my(our) assigns withdraw this authorization in writing.

Send correspondence to: **BACON & THOMAS, PLLC**
625 Slaters Lane - 4th Floor
Alexandria, VA 22314-1176

Telephone Calls to: **J. Ernest Kenney**
(703) 683-0500

FULL NAME OF FIRST OR SOLE INVENTOR	CITIZENSHIP
Heinz HORNUNG	**Germany**
RESIDENCE ADDRESS Weichselbaumer Straße 15, D-82205 Gilching, Germany DEX	POST OFFICE ADDRESS IS THE SAME AS RESIDENCE ADDRESS UNLESS OTHERWISE SHOWN BELOW
DATE 09 April 2001	SIGNATURE Heinz Hornung

☒ *See following page(s) for additional joint inventors.*

CONTINUATION OF DECLARATION FOR PATENT APPLICATION AND APPOINTMENT OF ATTORNEY

PRIOR FOREIGN APPLICATION(S) (35 USC §119)			PRIORITY CLAIMED	
Number	Country	Day/Month/Year Filed	Yes	No

PRIOR PROVISIONAL APPLICATIONS 35 U.S. CODE §119(E)	
Application Number	Day/Month/Year Filed

PRIOR U.S. OR PCT INTERNATIONAL APPLICATIONS (35 U.S. CODE §120)		
Application Number	Filing Date	Status - Patented, Pending or Abandoned

FULL NAME OF JOINT INVENTOR Achim PHILIPP	CITIZENSHIP Germany
RESIDENCE ADDRESS Furstätter Strasse 17, D-83059 Kolbermoor, Germany DEX	POST OFFICE ADDRESS IS THE SAME AS RESIDENCE ADDRESS UNLESS OTHERWISE SHOWN BELOW
DATE 09.04.01	SIGNATURE Achim Philipp

FULL NAME OF JOINT INVENTOR	CITIZENSHIP
RESIDENCE ADDRESS	POST OFFICE ADDRESS IS THE SAME AS RESIDENCE ADDRESS UNLESS OTHERWISE SHOWN BELOW
DATE	SIGNATURE

FULL NAME OF JOINT INVENTOR	CITIZENSHIP
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DATE	SIGNATURE

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☐ *See following pages for additional joint inventors/priority applications.*